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Assessment of infrazygomatic bone depth for mini-screw insertion

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Abstract

Objective: To investigate the bone depth at the infrazygomatic crest with regard to orthodontic mini-screw insertion.

Material and methods: Twenty-nine adult human dry skulls were imaged using CBCT technology, slice data were generated and multiple measurements were undertaken at three sites associated with the infrazygomatic crest and five different measurement levels. The data were analyzed using intraclass correlation and repeated measures ANOVA.

Results: The greatest bone depth was available at, on average, 11.48 $\pm$ 1.92 mm apical from the cemento-enamel junction of the maxillary first molar and decreased rapidly further apically. Maximum bone depth (7.05 $\pm$ 3.7 mm) was present at the lowest measurement level. However, here, insufficient clearance to the molar roots was present. Both the measurement site and the level at which the measurements were conducted had a significant impact on bone depth.

Conclusions: When inserting orthodontic mini-screws (6 mm or longer) into the infrazygomatic crest while staying clear of the molar roots perforation of the maxillary sinus or the nasal cavity can be expected, but bone depth varies considerably between individuals.

Absolute anchorage through the use of one or more mini-screws has become an integral part of modern orthodontic practice (Melsen 2005). Recently, reports proposing an anchorage site suitable for single mini-screw insertion for corrections in the vertical dimension have appeared in the literature: the infrazygomatic crest (Kuroda et al. 2004; Liou et al. 2007). Topographically, this insertion site is located on the buccal surface of the zygomatic process of the maxilla, above the first permanent molar (Fig. 1). When placing mini-screws at this site for orthodontic purposes, it is important to understand the anatomical dimensions that can be expected. However, to date, not much is known about the bone volume of the infrazygomatic crest. CT imaging suggests that the bone available to anchor a mini-screw at this site presents as a rectangular space with distinct borders within which navigation of the mini-screw should take place during the insertion procedure (Fig. 2). A study conducted by Liou et al. (2007) investigated bone thickness above the mesio-buccal root of the maxillary first molar and revealed that on average sufficient bone thickness is available for a 6 mm implant if placed at a specific angulation to the occlusal plane. To date, a detailed investigation of the infrazygomatic crest space cannot be found in the literature.

Therefore, the purpose of this study is to investigate the available bone depth at the

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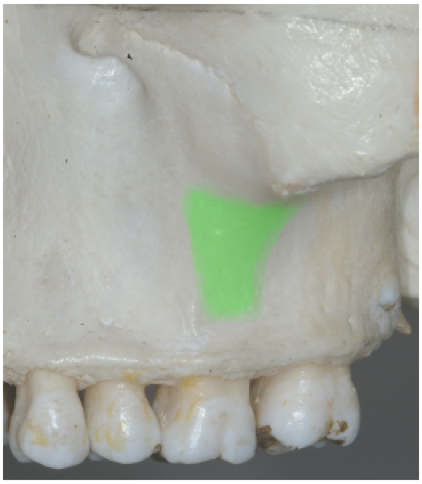

Fig 1. Topographical location of the infrazygomatic crest (green highlight).

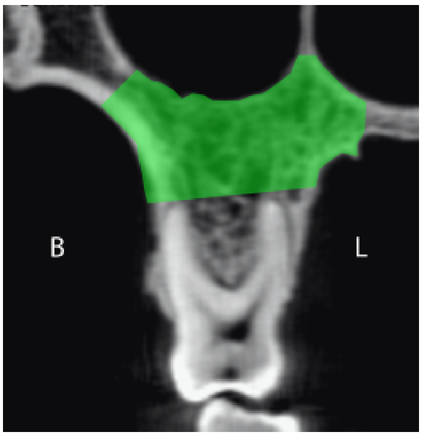

Fig 2. Illustration of the osseous infrazygomatic crest space (green highlight).

infrazygomatic crest with regard to placing orthodontic mini-screws at this site.

Material and methods

Sample

The sample consisted of 29 adult human dry skulls from the Hamann–Todd Osteological Collection at the Cleveland Museum of Natural History, Cleveland, OH (26 males/three females – average age: 30.1 ± 10.8 years), which were collected in the first half of the past century. Inclusion criteria were intact maxillary jaws and the presence of maxillary second bicuspids, first molars and second molars.

Imaging technology

These skulls were imaged with a state-of-the-art *CBCT* unit (Hitachi CB Mercuray™

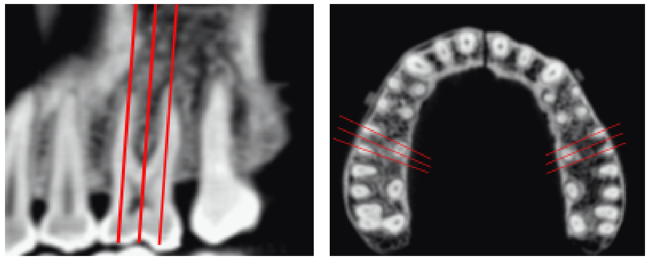

Fig 3. Orientation of the cuts (red) in the sagittal (left) and coronal (right) plane.

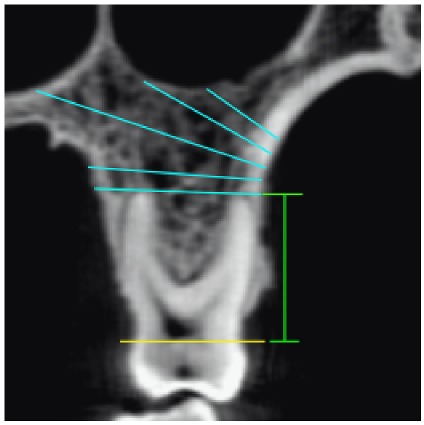

Fig 4. Measurements of bone depth (blue) and vertical dimension (green).

– Hitachi Medical Corporation, Tokyo, Japan) at a 9 in. field of view, 100 kVp and 10 mA. The resulting voxel size was 0.28 mm. Using Accurex™ software (CyberMed Inc., Seoul, Korea), slices were reconstructed at three sites on either side, oriented perpendicular to the buccal bone surface and parallel to the long axis of the maxillary first molar (Fig. 3):

1. Root tip of the mesio-buccal root of the maxillary first molar (MB).
2. Middle of the buccal furcation of the maxillary first molar (equal distances to mesial and distal buccal root) (IR).
3. Root tip of the disto-buccal root of the maxillary first molar (DB).

Measurements

On each of these slices, five measurements of depth and one measurement of vertical dimension were conducted. Measurements of depth investigated the relationship between the buccal bone surface and the cranial, lingual and caudal borders of the available osseous space. Measurements of vertical dimension investigated the vertical height of the first depth measurement (Fig. 4).

Measurements of depth: At sites 1 and 3, the first measurement of depth was conducted perpendicular to the buccal bone surface tangent to the tip of the mesio-buccal or the disto-buccal root tip, respectively. The following four measurements were taken increasingly cranial at 1 mm increments again perpendicular to the buccal bone surface. At site 2, the first measurement was taken at the level where the width of the furcation reached and remained at 2.5 mm or more, which appears to be the minimal inter-radicular distance required to insert a mini-screw of 1.5 mm or less in diameter (Maino et al. 2005). The following four measurements were taken in the same manner as described above.

Measurements of vertical dimension: One measurement of vertical dimension was carried out on every slice to determine the shortest distance between the first measurement of depth and the cemento-enamel junction (CEJ).

Measurements on 10 slices were carried out twice with a 2-week time interval between them to collect data for the intrarater reliability assessment.

Data analysis

All data analyses were carried out using SPSS™ 16.0 (SPSS Corp, Chicago, IL, USA). The significance level for all the tests was set at $P \leq 0.05$. Preliminary data analysis revealed a normal frequency distribution of the sample (Shapiro–Wilk test) and led to the assumption of sphericity (Mauchly's test of sphericity). Intraclass correlation was used to test intrarater reliability. Paired Student's *t*-test was used to analyze for differences between measurements of the left and the right side. No statistically significant differences were found and so the data were pooled. Two-way repeated measures ANOVA was used to test for differences in bone depth at the different measurement levels.

Results

Intrarater reliability was high for both measurements of bone depth ($r = 0.89$) and measurements of vertical dimension (0.91).

Measurements at all three sites exhibited a similar pattern. The first, most coronal measurement yielded the largest bone depth value (MB: 6.69 ±4.27 mm; IR: 7.05 ± 3.07 mm; and DB: 6.17 ± 4.23 mm). Thereafter, the values decreased gradually until the smallest value was recorded at the fifth, most apical measurement (MB: 3.6 ± 3.6 mm; IR: 3.57 ± 3.08 mm; DB: 2.97 ± 3.64 mm). However, with the standard deviation (SD) ranging from 52% to 122% of the mean values, dispersion, as a measure for individual variation within the sample, was high (Table 1). Statistical analysis revealed that both the anterior–posterior position relative to the first molar roots ($P = 0.003$) and also the measurement levels ($P = 0.001$) had a highly significant impact on bone depth.

The height of the first measurement was located on average 10.36 ± 2.04–12.18 ± 1.76 mm, depending on the measurement site, apical from the buccal CEJ of the maxillary first molar. The largest distance was recorded at the mesio-buccal root, followed by the disto-buccal root, while the buccal furcation presented with the least distance from the buccal CEJ to the first measurement (Table 2).

Table 1. **Descriptive statistics for bone depth of the infrazygomatic crest space at three measurement sites (*n* = 58)**

Site	Level										Total	
	1		2		3		4		5			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
MB	6.69	4.27	5.62	4.25	4.75	4.15	3.89	3.48	3.6	3.6	4.91	4.1
IR	7.05	3.7	6.23	4.1	5.1	3.9	4.02	3.21	3.57	3.08	5.19	3.83
DB	6.17	4.23	5.18	4.44	3.87	3.78	3.15	3.36	2.97	3.64	4.27	4.08

MB, mesio-buccal root; IR, buccal furcation; DB, disto-buccal root.

Table 2. **Descriptive statistics for the height of first measurement (*n* = 58)**

Site	Height	
	Mean	SD
MB	12.18	1.76
IR	10.36	2.04
DB	11.9	1.39
Total	11.48	1.92

MB, mesio-buccal root; IR, buccal furcation; DB, disto-buccal root.

Discussion

Before one can determine whether sufficient bone depth exists at the infrazygomatic crest, a brief discussion of the optimal mini-screw length is justified. To date, no conclusive evidence exists whether implant length is a decisive factor for primary stability or long-term success (Miyawaki et al. 2003; Miyamoto et al. 2005). It appears that other factors such as bone quality, implant site preparation or implant diameter play a significantly larger role (Miyawaki et al. 2003; Miyamoto et al. 2005; Wilmes et al. 2006, 2008). While a longer implant seems to have no advantage over a shorter implant with regard to failure rates, it certainly has disadvantages with regard to potential side effects. A longer implant has a higher likelihood of damaging adjacent structures. Therefore, all things being equal and within reasonable limits, a shorter mini-screw should be preferred over a longer implant. Most manufacturers offer mini-screws of different lengths in their systems, the shortest being 6 or 7 mm long (Baumgaertel et al. 2008). To prevent damage to adjacent structures when placing an orthodontic mini-screw, a certain safety distance is required. Unfortunately, with recommendations ranging from 0.5 mm (Maino et al. 2005) to 2 mm (Liou et al. 2004), there is no agreement in the current literature on the magnitude of the required safety distance. In a study assessing mini-screw stability, Liou et al. found that the average movement of an orthodontic mini-screw was on average <0.5 mm at the implant head (Liou et al. 2004), and Maino et al. (2005) recommend 0.5 mm as the minimal safety distance to any adjacent anatomical structure . To reflect an ideal scenario, the present study used 0.5 mm as the safety distance, the minimum recommendation in the current literature. When determining the minimal interradicuar distance, the implant outer-core diameter has to be taken into account as well. For a 1.5-mm-diameter mini-screw, the minimal interradicuar distance should therefore be 2.5 mm.

The results of this study indicated that with an average bone depth of 6.17–7.05 mm at the lowest measurement level, sufficient depth existed, on average, for the insertion of a 6-mm orthodontic mini-screw without perforating into the sinus. However, the first measurement was taken tangent to the root tip. This means that placement at the first level would violate the minimal safety distance as explained above and therefore cannot be recommended. Further apically, where sufficient clearance to the roots existed, bone depth decreased rapidly with every measurement level. This means that further apically a perforation of the maxillary sinus was likely, even when using the shortest orthodontic mini-screws currently available. An exception is the IR measurement at ML 2, which provided 6.23 mm of bone depth. The high SD observed in this study proved that marked individual variation existed in the region of interest (ROI) (Fig. 5). Statistical analysis indicated a significant effect of both the measurement level and the measurement site on bone depth, which suggests that in order to maximize the amount of bone depth available the insertion should take place above the furcation at the lowest level possible. In their study, Liou et al. (2007) found a narrow range where, on average, sufficient bone depth for a 6 mm implant existed at the infrazygomatic crest, but it was dependent on the angle of insertion.

The level of the greatest bone depth was located on average 11.48 mm apical from the buccal CEJ of the maxillary first molar. This would indicate the ideal level for mini-screw insertion. More in detail, at the mesio-buccal root, the ideal insertion site would be located farthest in the vestibule, on average 12.18 mm apical from the CEJ. In the furcation, the insertion site should be 10.36 mm from the CEJ, which is the lowest level of the three measurement sites. At the disto-buccal root, the mini-screw should be inserted on average 11.9 mm from the CEJ. This was to be expected and reflects the contor of the

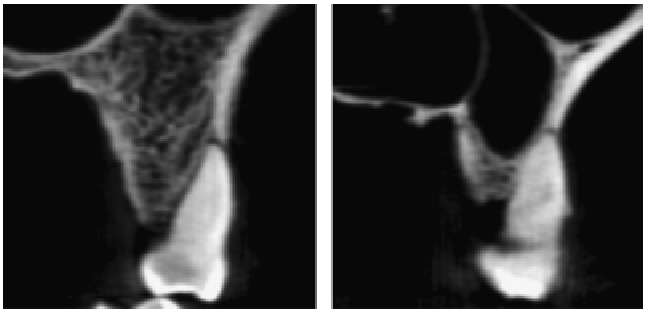

Fig 5. Individual variation: specimen with maximum bone depth (left) and minimum bone depth (right).

buccal roots of the maxillary first molar. However, all these insertion sites are located so high in the vestibule that implants would most likely be inserted deep in the mucosa. This is unfavorable as it can result in tissue overgrowth, irritation or discomfort to the patient (Kravitz & Kusnoto 2007; Baumgaertel et al. 2008).

These findings are comparable to the findings of Liou et al. (2007), who measured the height of the insertion site not from the CEJ but from the occlusal plane at the mesio-buccal root only.

The infrazygomatic crest space was a rectangular osseous volume that was limited by certain distinct borders. The buccal border of the infrazygomatic crest space was represented by the course of the outer surface of the zygomatic process of the maxilla and the most apical regions of the alveolar process. The cranial border was characterized by the floor of the maxillary sinus and/or the floor of the nasal cavity. The medial border consisted of the lingual root of the maxillary first molar, the lingual surface of the alveolar process and the surfaces of the nasal cavity. The caudal border consisted of the mesio- and disto-buccal roots of the first permanent molar. These anatomical structures that constituted the borders of the ROI showed with marked individual variation, which explains the relatively high SDs in the bone depth measurements. Root length, pneumatization of the maxillary sinus, bucco-lingual inclination of the maxillary first molar, alveolar processes height and depth and morphology of the buccal furcation were probably the most important variables that determined how much bone depth was available for mini-screw insertion.

This study demonstrated that on average, mini-screw insertion (6 mm length or more) could lead to perforation of the maxillary sinus or the nasal cavity. However, in rare cases, given favorable anatomical relationships sufficient bone depth existed for placement of up to 12-mm-long implants without any perforation.

Small perforations of the maxillary sinus or the nasal cavity as they may occur when placing orthodontic mini-screws usually go unnoticed because they heal on their own and without any complications (Brånemark et al. 1984; Raghoebar et al. 1999; Ardekian et al. 2006). If a perforation is noticed, interruption of orthodontic treatment or removal of the implant is generally not warranted. The patient should be informed and monitored closely because in very rare cases, perforations of such sort may lead to sinusitis or mucoceles (Kravitz & Kusnoto 2007). Assessment of the risk–benefit ratio of this procedure needs to be carried out on an individual basis considering the patient's goals and desires (Tulloch & Antczak-Bouckoms 1987; Cassidy et al. 1993).

Conclusion

When inserting orthodontic mini-screws (6 mm or longer) into the infrazygomatic crest, perforation of the maxillary sinus or the nasal cavity can be expected. However, the anatomy at this site varies considerably between individuals.

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